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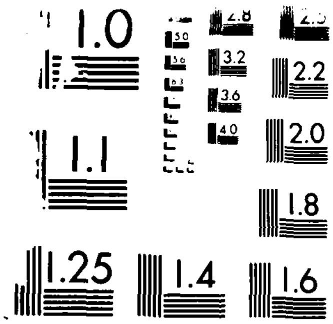
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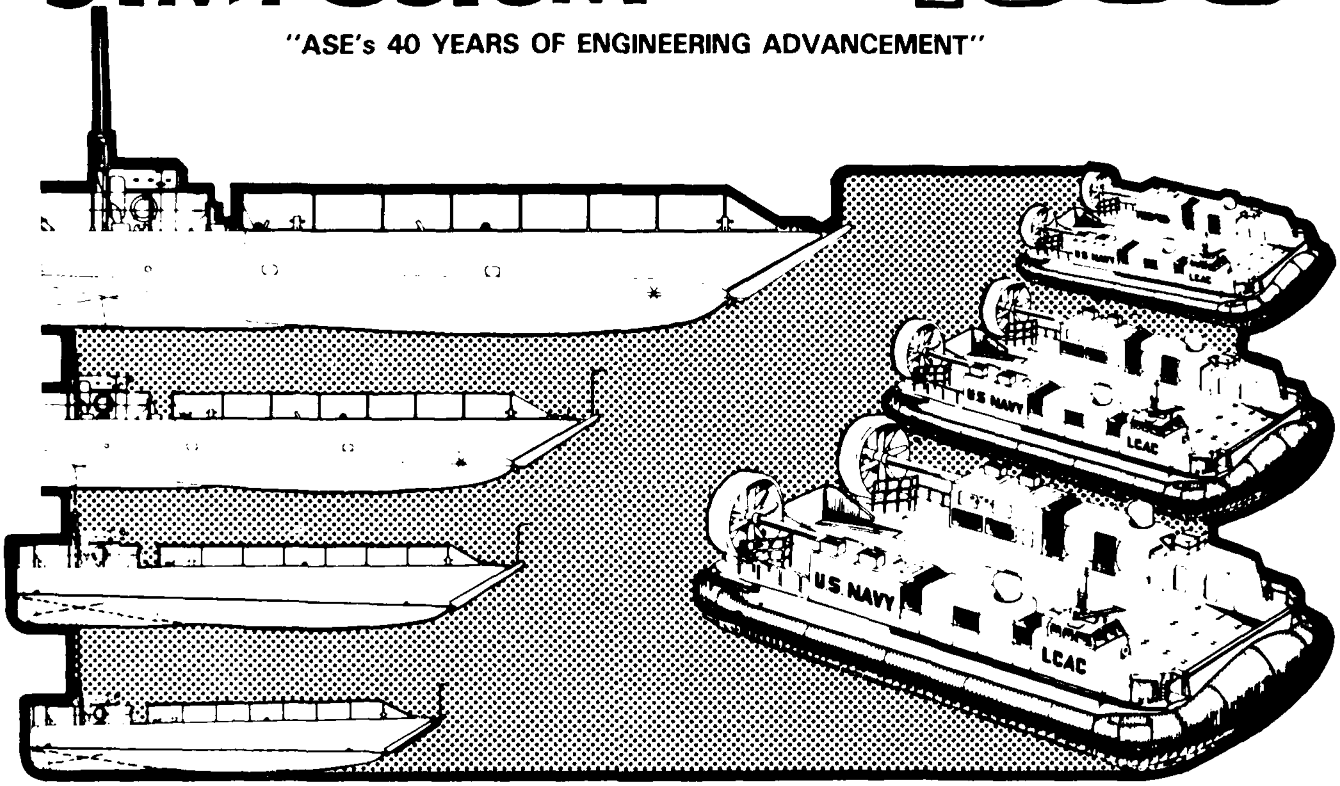

SHIPBOARD HF ANTENNA TILTING MECHANISM

by: R. Biondi

ASSOCIATION OF SCIENTISTS AND ENGINEERS OF THE NAVAL SEA SYSTEMS COMMAND • DEPARTMENT OF THE NAVY • WASHINGTON, D.C. 20362

SHIPBOARD ANTENNA TILTING MECHANISM
(SATM)

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ABSTRACT

Nearly every ship in the fleet requires antennas 14 to 35 feet in length (single monopoles, trussed monopoles or twin whips) for High Frequency communications. Frequently, the antennas must be installed in an area that obstructs a field-of-fire for a weapon, interferes with flight operations, hinders underway replenishment (UNREP), or other operational requirements. When any of these conditions exist, provisions must be made to tilt the antenna to a position where it does not interfere with the operational requirement.

In the ship design process, the antenna to be used and its location have been carefully analyzed and specified. The methods used to tilt the antenna, however, have been left to the discretion of the various shipyards. This has resulted in scores of various electro-mechanical, hydraulic, and hybrid tilt mechanisms with poor reliability, lack of logistics support, excessive weight, and a host of other deficiencies.

To address the increasing severity of this problem, the Space and Naval Warfare Systems Command has developed a modular electro-mechanical antenna tilting system that is to be the standard for the fleet for all tilting requirements. It has been fully tested and complies with MIL-E-16400 and associated specifications and will have complete technical documentation and logistics support. This paper describes the deficiencies of existing systems and how the design of the modular "Shipboard Antenna Tilting Mechanism" (SATM) resolves these problems.

TABLE OF CONTENTS

FIGURES

SHIPBOARD ANTENNA TILTING MECHANISM (SATM)

INTRODUCTION

The trend in Naval ship communications systems design, in particular the topside configuration, has been one in which an increasing number and variety of antenna devices have contested for the finite topside space available. The inherent nature of antennas, both electrically and structurally, places significant physical limitations as to how they may be located in relation to each other and to other systems and structure. Careful attention to location selection prevents loss of efficiency, degradation of pattern, and electromagnetic interference. Although more severe in combatants, these difficulties are nonetheless apparent in amphibious and auxiliary class ships.

In an effort to alleviate the restrictions on communications antenna spacing, and to accommodate the inevitable trade-offs required in arriving at an optimal configuration, the topside integration designers, must, as a matter of necessity, resort to time-sharing of systems according to priority of operational need. When communications antennas are involved, tilting devices are employed to displace the antenna from the operating space required for another operational requirement such as flight operations, field-of-fire for a weapons system, or underway replenishment. This solution has been applied with increasing frequency as the demand for space to accommodate additional systems increases.

Although careful design consideration is given to the location of antennas, it has been common practice that the selection and design of the tilting device, a miscellaneous item of equipment, was left to the discretion of the shipyard in both new construction and alterations. As a result, there are many different types of devices in the fleet of inferior design. Major design limitations are:

- Each tilting device has been designed for its own limited end requirement. Standardization is nonexistent and devices are seldom interchangeable.

- With one exception, logistics support and configuration control is non existent.

- Devices weighing more than a ton are used to tilt an antenna weighing two hundred pounds or less.

- Designs have centered on simple time-load performance factors and have largely ignored environmental considerations, safety, maintainability, and reliability.

- Both hydraulic and gear driven actuators are used with many variations in the designs of each.

- Life cycle costs to attain even marginal performance are excessive.

TYPICAL PROBLEMS

Continuing problems with nearly all designs include: Failure of cast parts under shock loads, corrosion of relays and contacts, corrosion of bushings and other ferrous components, high failure rates of hydraulic systems, vulnerability of exposed hydraulic lines to operational and combat damage, and manual tilt features that are difficult and frequently dangerous to operate. Typical problems found throughout the fleet are described in the following examples:

- The CG-26 twin whip tilt base assembly shown on the fan tail in the vertical position (Figure 1-1) is an electrohydraulic tilt system actuated by a hydraulic power unit located below deck. The "remote" electrical controls are on deck adjacent to the device with a manual backup pump located below deck.

- The platform and ground plane is approximately 3 feet by 8 feet and provides little protection to hydraulic lines and close tolerance machined components. Exposure of actuator pistons to salt buildup can cause eventual damage to seals and result in leaks. Total system weight is estimated to be in excess of 2,000 pounds.

- Shown in the tilted position (Figure 1-2) the device presents an extremely large surface exposed to overpressure effects from a 5" gun located just forward of the device. The cast aluminum tilt bases with relatively small attachment flanges may be susceptible to failure, since failures have occurred at these locations in underwater shock tests.

- A geared actuating device is shown in Figure 2-1 on the CGN-37 class. It is electrically driven by a 2 horsepower motor. The device is massive and occupies approximately 15 feet of deck space to tilt the twin antennas via a torsion bar supported by pillow blocks. Since no fittings were provided for lubrication, bushings in the pillow blocks corroded and froze (Figure 2-2), causing the motor to burn out. With no logistics support, over two years were required to rebuild the motor and repair the device.

- A major complaint by operators was the force required and time consumed in manual operation. The majority of the devices in the fleet are manually operated and differ in design between ship class, and in many cases within a class. Most use a counterbalance weight to control loads in rotating the antenna (Figure 3). Locking pins must be removed and inserted in vertical and horizontal positions. Due to their location, these type devices are difficult and dangerous to operate particularly in heavy seas. Many injuries, including loss of limbs, have been reported during the operation of these devices. Weight is excessive for a manually operated system and will vary between 600 and 1,500 pounds depending on the particular design.

Most problems are the direct result of nonstandardization, a lack of logistics support, and consideration of all pertinent design factors that impact reliability and maintenance.

In 1981, a low level effort called the Shipboard Antenna Tilting Mechanism (SATM) project was initiated aimed at identification of the requirements for an antenna tilting device that would resolve the problems with existing systems. A standard design with modular features enabling the device to support all existing and anticipated requirements was developed. The varieties and deficiencies of existing systems were studied in detail and design goals and specifications determined. In 1983, an Advanced Development Model of SATM was manufactured, incorporating the design features required to eliminate or minimize existing deficiencies. The remainder of this paper discusses the design rationale and describes the resultant system.

DESIGN GOALS

It was readily apparent, following extensive review of documented failures, shipchecks, and discussions with fleet personnel, that most problems were caused by poor reliability of hydraulically actuated systems. Most are relatively complex, require a disproportional amount of space and weight for a simple, low duty-cycle function of this type, and are extremely vulnerable to damage under normal operating as well as combat conditions. An electromechanical gear actuated device was selected for the following reasons:

- Reliability in the required operating environment is more assured
- Installation requirements are less demanding
- Vulnerability to operational and combat damage is reduced since components can be more adequately enclosed and protected
- Hydraulic systems are sensitive to environmental pollution and require more preventive and corrective maintenance
- Space and weight requirements can be considerably reduced
- Modularity and standardization can be more cost-effectively attained and implemented

A number of gear driven and hydraulic actuator designs were considered before finally selecting an epicyclic (planetary) gear drive form. This drive offers a high torque-to-weight ratio, high static load capacity, relative economy, and makes possible a design that eliminates the need for locking pins to withstand applied loads which have been a source of problems in existing systems.

Modularity was a primary objective in the design in order to allow reconfiguration by addition or deletion of component parts to support any of the configuration requirements, both structurally and electrically.

It was recognized early in the analysis that the minimum weight feasible to meet required nonwaveslap conditions was in conflict with specifications necessary to meet the loads encountered in greenwater conditions. For this reason, the modular concept was expanded to encompass a family of devices sharing a common modular design with maximum use of commonality in components.

GENERAL DESCRIPTION

The SATM is comprised of two basic groups:

1. A heavy duty (HD) Antenna Tilting Group (ATG) intended for low freeboard, deckedge installations exposed to waveslap (the impact of green water (solid, not spray) against the weatherdeck components).

2. A lightweight (LW) Antenna Tilting Group (ATG) supporting tilting requirements in areas not exposed to green water loads and intended for installations higher in the superstructures where weight is an important factor.

The remainder of this article addresses the description of the HD ATG. The LW ATG follows the HD design concept with a high degree of commonality of components. Weight reduction, the primary objective, as a result of lower static load requirements, is attained primarily by reduction in size of the pedestal and gear drive assembly and reduction of wall thickness of structural members.

Each group is available in four variants, the variation being descriptive of two factors in combination: whether the requirement is for manual control only or powered control, and whether the requirement is to support a single or twin antenna.

The twin HD configuration shown in both raised (Figure 4-1) and lowered (Figure 4-2) positions is the heaviest of the variants at 1,250 pounds. Overall dimensions are:

Height erect	42"
Depth	20"
Width (Twin Antenna)	80"
Width (Single Antenna)	56"
Height lowered	27"

With a 3-inch foundation the height of the ATG, when lowered, is not greater than 30 inches and complies with Navy and FAA specifications for equipment located in the peripheral area of flight deck and helo landing areas. Both HD and LW ATGs have common installation and operating envelope dimensions.

Configuration options are shown in Figure 5. Electrical components are common to both HD and LW ATGs. A manually controlled device can be upgraded to an electrically operated device with local control or upgraded further to provide remote control.

Any antenna and associated tuners or couplers can be installed by use of adapters on the antenna mounting platforms which are designed to accommodate antenna type AS-2537A.

A feature not available on any existing device provides the capability to tilt the antenna inboard to any angle up to 90 degrees when permitted by adjacent structures. For safety reasons, this can be accomplished by manual control only. In many cases, this will eliminate a requirement for crane service to change out an antenna or remove it for maintenance or repair.

The HD group has been qualified to MIL-E-16400 specifications for temperature, humidity, Grade A shock, inclination, icing and dust. The LW groups will undergo similar tests this year. Careful attention to corrosion control during the design process, including selection of corrosion resistant materials, dissimilar metals, and environmental protective measures will provide significantly improved performance with minimum maintenance.

MECHANICAL

The primary actuating element, (Figure 6) is a minimum backlash gear reduction drive composed of a pure couple, two-stage epicyclic (planetary spur) gear group. First stage handcrank gearing is 6.13 to 1 and second stage 382.5 to 1. The manual handcrank is engageable to first stage gearing and automatically releases for power operation to prevent handcrank rotation.

Gear load distribution is delivered through four-point engagement. Final output of 2345 to 1 is delivered through a wide face internal annulus gear manufactured from high alloy heat treated steel. All gear components are manufactured to AGMA quality 8 standards. The drive assembly components are concentrically arranged about a common shaft. Assembly/disassembly requires less than two hours. No special tools are required for any variant.

Elimination of the need for locking pins was realized by designing the drive system with minimum backlash and four-point engagement of the planetary assembly augmented by a 15 foot-pound brake on the drivemotor.

The HD device provides over 1,000,000 lbs.-in. static torque holding capacity. The LW device, using the same approach, supports 500,000 lbs.-in. static capacity for nonwaveslap loading.

A compression loading bumper stop is engaged at the extremes of vertical and horizontal rotation. This relieves vibration loads from the hull into the gear assembly and prevents or reduces fretting of gear teeth while providing a positive stop as a safety factor at extremes of rotation.

The gear assembly is watertight. A double seal operates on a hard chrome race to maintain watertight integrity and contamination of lubricant. Lubrication is splash type using MIL-H-5606 hydraulic fluid. No leakage has occurred in over 4,000 cycles of operation.

The pedestal assembly contains all actuating elements with the exception of remote control and motor controller components. The gear drive, brakemotor, cams, cutout switches, local control, and integrating hardware are conveniently located and easily accessible for maintenance.

The cross-sectional areas presented to overpressure effects are at a minimum. The 17-inch by 19-inch footprint of the pedestal in all variants minimizes deck space utilized.

ELECTRICAL

For powered variants, a 2 horsepower, 440 volt, 60 cycle, 3-phase reversible brakemotor provides electrical power to the unit. Control circuits are 115 volts, which permit operation up to 1,200 feet from a remote control station. The local control switch on the pedestal permits local control on deck for lowering or raising the antenna and provides a disable function to remote control for maintenance safety. An overtravel cutout switch removes power from the motor in the event of limit switch override.

The remote control (Figure 7) will control up to three tilting groups. It is normally placed in CIC or flight deck control. It provides momentary switches for cycling between vertical or lowered positions, indication of position, and source of control: i.e., local (on deck) or remote (CIC). The antenna rotation can be stopped in any position between limits.

A 3 X 3 matrix of 9 double-pole, double-throw switches is used, with only 1 set of contacts required for operation. The switches may be interchanged to pick up the unused set of contacts. This permits interchangeability to re-establish contact in the event of failure.

A remote indicator having no control features provides indication of antenna position in the communicator's space.

PERFORMANCE SUMMARY

The ATGs, in all variants, offer many improvements over existing devices. For example, the USS KITTY HAWK is reported to have required approximately 1 1/2 hours to lower all antennas in preparation for getting underway for flight operations. The SATM will lower all antennas on a carrier in less than 30 seconds. Specifications and operating parameters are as follows:

Operating Speed - Powered

- Lower 19 sec.-90°
- Raise 20 sec.-90°

Operating Speed - Manual Handcrank

- 100 turns @ 25 lb/ft torque

Tilt Angles

- Outboard - 0° to 135° preset to requirement
- Inboard - manual only to any position to 90°

Start/Stop

- Any angle within prescribed limits

Static Load Capacity (HD)

- 1,000,000 in.-lb.

Dynamic Load Capacity (HD)

- 196,000 in.-lb.

Static Load Capacity (LW)

- 500,000

Dynamic Load Capacity (LW)

- 100,000 in.-lb.

Locking Pins

- None required. Uses minimum backlash planetary gear train. 2350-1 ratio (approx)

Load Options

- Twin Broadband Antennas (with termination box)
- Single Receive Antenna (with termination box)
- Single Transmit Antenna (with tuner)

Control

- Manual only
- Powered local - manual backup
- Powered local and remote - manual backup
- To distance of 1,200 ft

MTBF

- In excess of 5,000 cycles

COST AND STATUS

The first production contract for first article and limited production will be awarded in April 1986 for CVN-73, CV-41, CG-62 through CG-65, and DDG-51 through DDG-54. CFE procurement for CVN-72 and LHD-1 through LHD-4 is programmed for FY86/87.

Unit costs in reasonable production quantities, i.e., 25, are expected to range from $25,000 to $50,000 depending on the variant or mixture of variants procured.

In contrast to most existing equipment, logistics support including technical manuals, spares, and SPCC supported parts will be an integral part of the SATM Program. Configuration control will be maintained by SPAWAR through the use of standard controlled drawings.

SPAWAR intends that the SATM will be specified for all future requirements for communications antenna tilting devices and supported fully in logistics and configuration control.

Figure 1-1

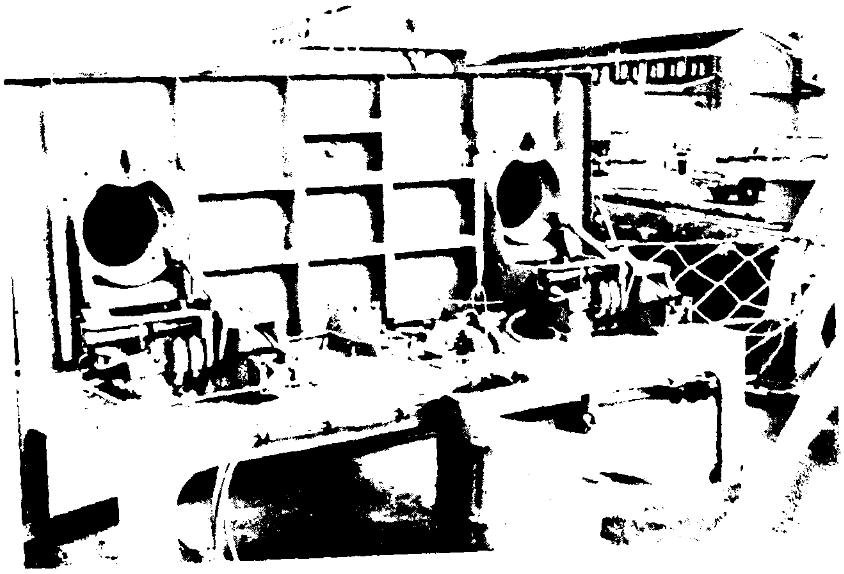


Figure 1-2

CG-26 ANTENNA TILT DEVICE (Both)

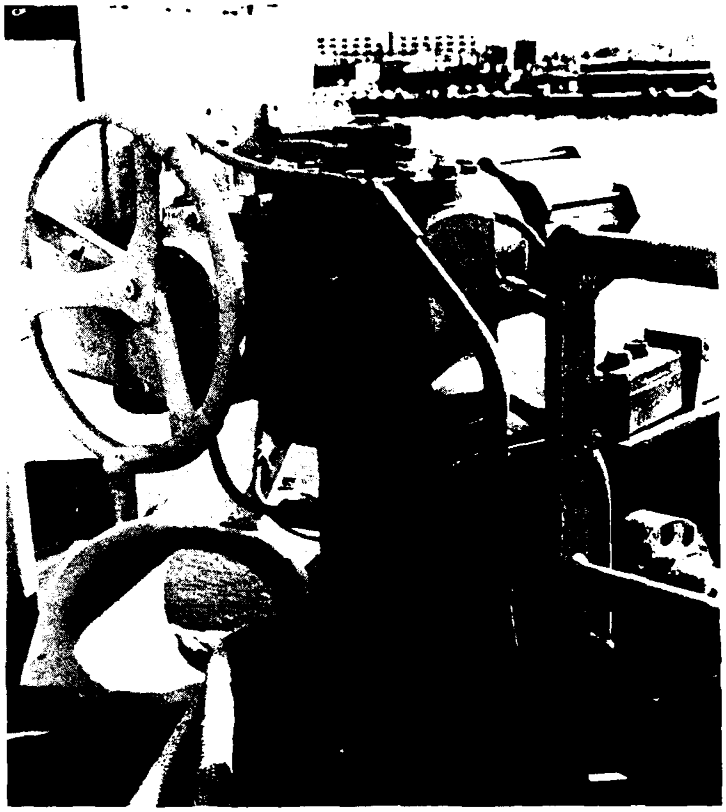


Figure 2-1
CGN-37 ANTENNA TILT-DRIVE UNIT

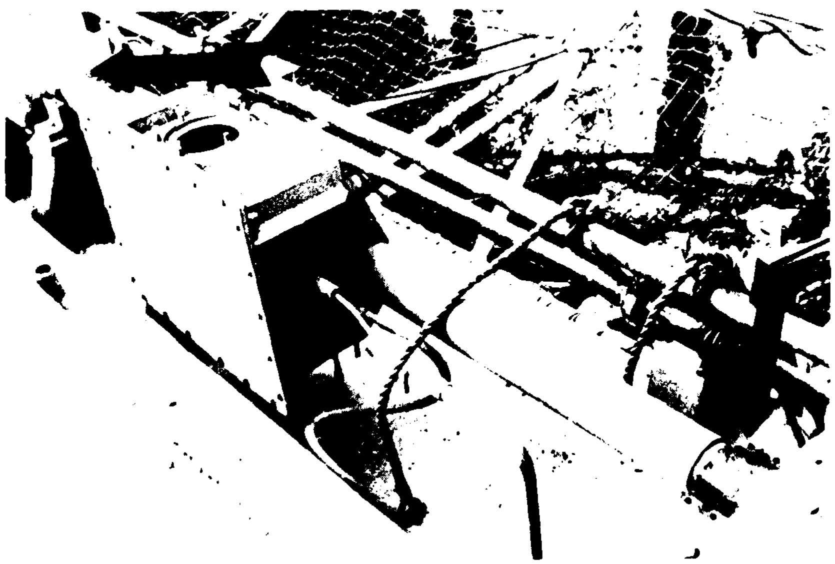


Figure 2-2
TORSION BAR ASSEMBLY

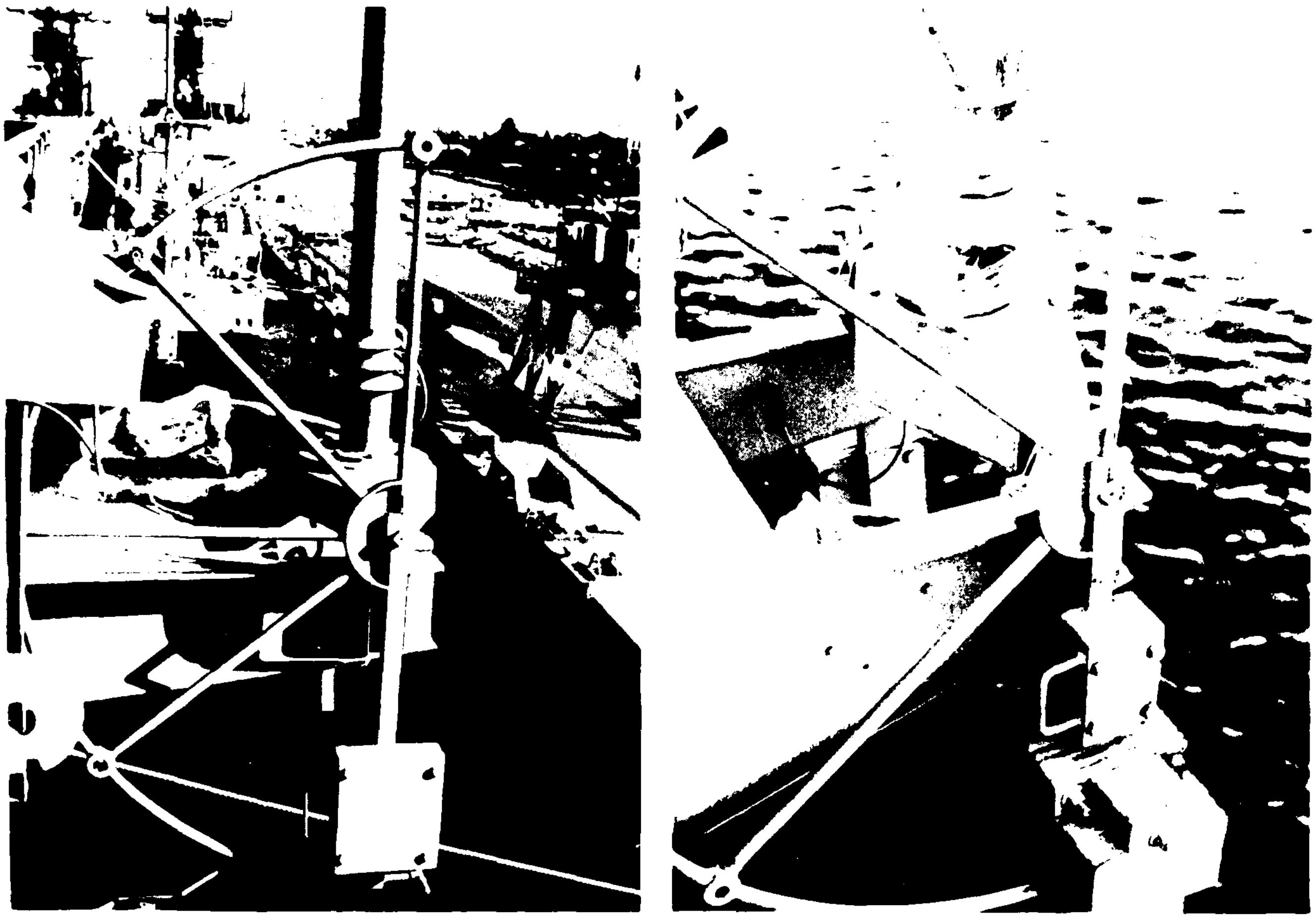


Figure 3
MANUAL TILTING DEVICES

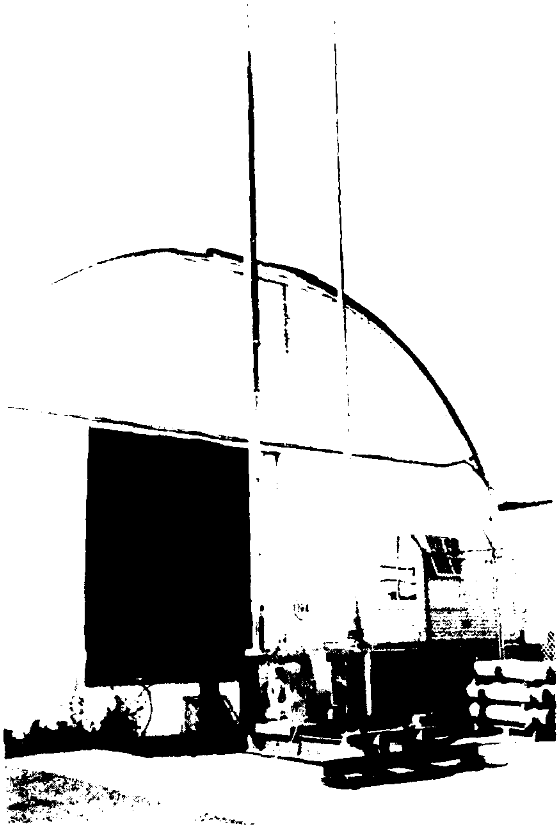


Figure 4-1

SATM
VERTICAL POSITION

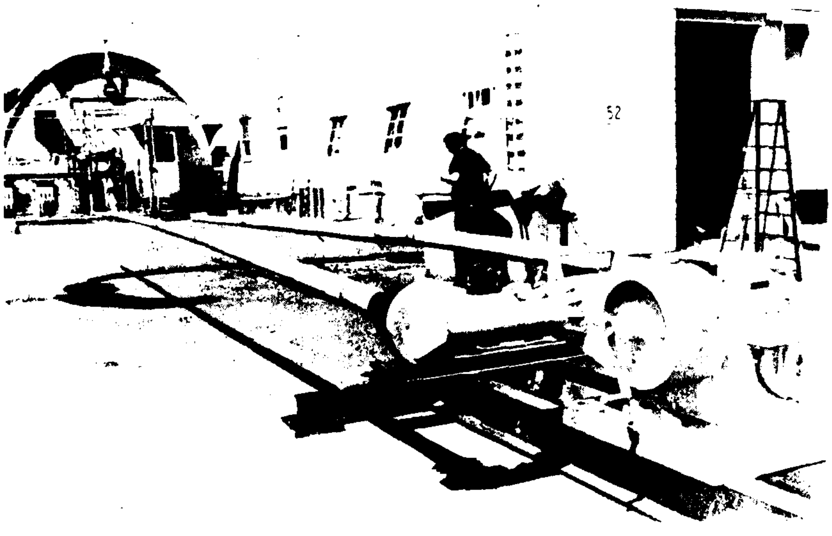
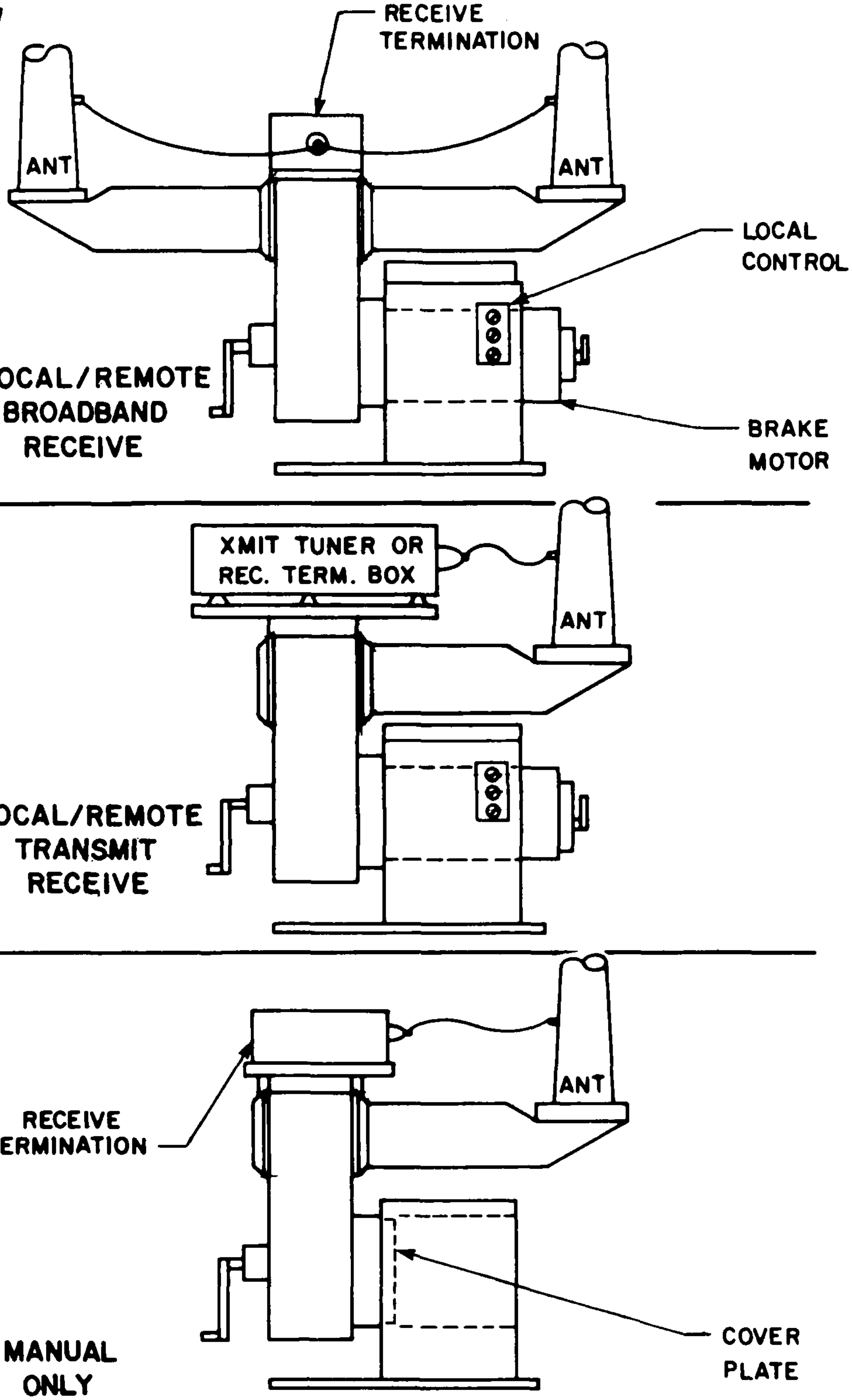


Figure 4-2

SATM
90° POSITION

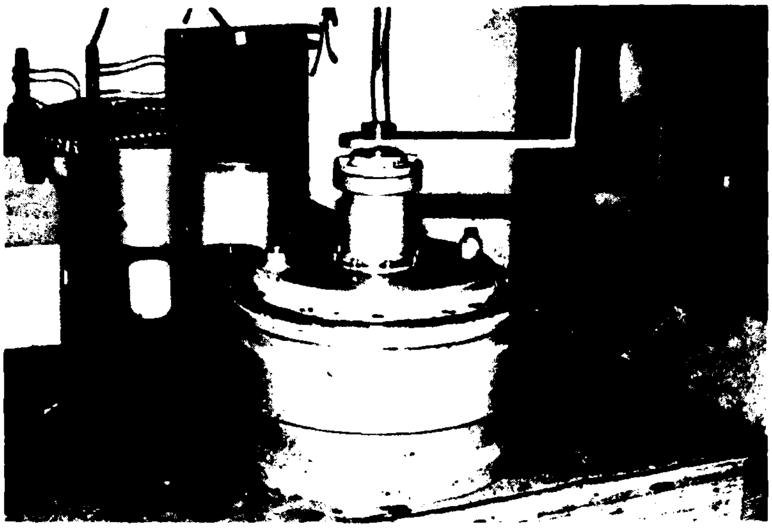
Configuration	RECEIVE	TRANS/REC	MANUAL	LOCAL CONT	RCU/RIU	BRAKE MOT	MOT CONT	LIMIT SW	COV PLATE
LOCAL/REMOTE BROADBAND RECEIVE	X		X	X	O	X	X	X	
LOCAL/REMOTE TRANSMIT RECEIVE	X	X	X	O	O	O	O	X	
MANUAL ONLY	X		X						X



O - OPTIONAL

HEAVY DUTY SATM CONFIGURATIONS

Figure 5



GEAR DRIVE AND
HANDCRANK ASSEMBLY

PLANET CARRIER
AND OUTPUT ANNULUS

PLANET CARRIER
ASSEMBLY

Figure 6

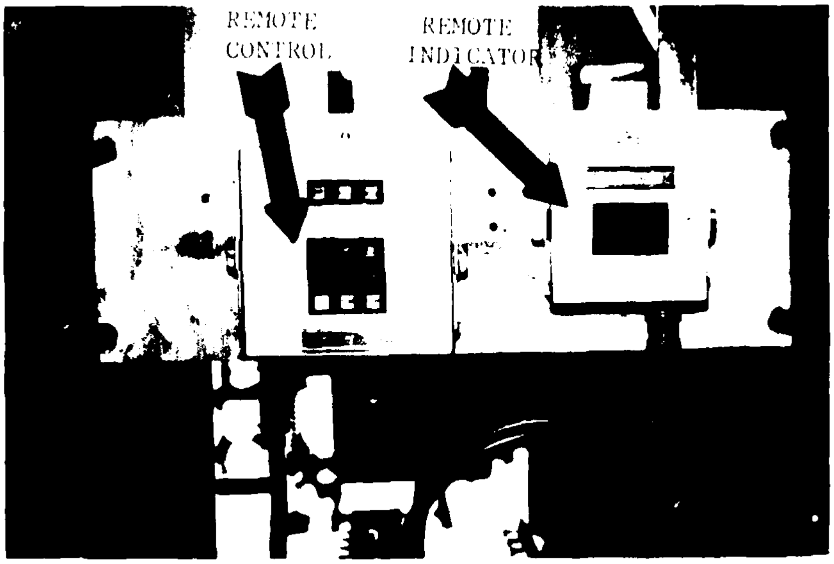


Figure 7

SATM REMOTE CONTROL AND REMOTE INDICATOR

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